GLAST Large Area Telescope

Calorimeter Subsystem

6.2 Thermal Design and Analysis

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Thermal Design

- **CAL Thermal Design is Passive**
  - **Primary Mode of Heat Transfer from the AFEE Card is Conduction Through the CAL Base Plate to the LAT Grid**
  - **Secondary Mode of Heat Transfer from the AFEE Card is Radiation from the CAL Side Panels to the LAT Grid Walls**
  - **No Dedicated Radiator**
  - **No Survival Heaters**

Thermal Design Drivers

- **Design Drivers –**
  - **A Total of 4 W Maximum is Dissipated from the CAL Electronics (1 W per AFEE Card) – Defined by AFEE Card Thermal Analysis**
  - **Majority of TEM Power Dissipated to the X-LAT Plate by Thermal Straps.**
  - **Survival Temperature Requirement Driven by Dual Pin Photodiodes**
  - **Survival Limit Cannot be Exceeded in Test**

Thermal Analysis – Tasks

- **Detailed Model of CAL Module**
  - **Construction of the Detailed Model Reflecting Actual Design**
  - **The Detailed Model Parameters Will Be Updated According to the Thermal Balance Test Measurements on the Engineering Module (In Particular, Contact Thermal Resistances Will Be Refined)**
- **Detailed Model of AFEE Card – Presented in Section 7.0**
- **Simplified Model of CAL Module**
  - **Correlation of Results With Detailed Model**
  - **Delivered to SLAC**

Thermal Analysis – Methodology

- **Static Analysis**
  - **Adjustment of the Conductances of the Simplified Model to Correlate the Results with the Detailed Model for the Hot and Cold Environment Cases**
- **Transient Analysis**
  - **10°C Temperature Step Applied on the Grid: Verification of the Correlation Between the Simplified and the Detailed Model**

Thermal Analysis – Design Limit Loads

CASE	THERMAL LOADS	
	MIN (deg C)	MAX (deg C)
OPERATING TEMPERATURE	-15	+25
SURVIVAL TEMPERATURE	-30	+50
ACCEPTANCE TEMPERATURE	-20	+40
QUALIFICATION TEMPERATURE	-30	+50

Thermal Analysis – Assumptions

- **Thermal Environment Design Parameters**

	Tracker	Grid	TEM
Temperature (°C)	18.5	18	34
Emissivity	0.04	0.75	0.04

Hot case

	Tracker	Grid	TEM
Temperature (°C)	-17	-15	-11
Emissivity	0.04	0.9	0.04

Cold case

Conductive coupling	Conductances (W/K)
Grid/base plate conductance (for each side: 4 sides)	2.67
TEM/base plate conductance (for each fixture: 4 fixtures)	0.03

- **Optical Properties**
  - **6 CAL Aluminum Faces:**
    - **Alodine 1200 Emissivity = 0.1**

Thermal Analysis – Assumptions

Material Properties

	Conductivity W/(m.K)	Specific heat J/(kg.K)	Density g/m^3
Composite (T300 1K PW/M76 ; 40% ; 124AW)	5	1.1	-
Aluminium 2618A	146	0.92	2.76
Aluminium 5754	132	0.945	2.67
CsI (Tl)	1.1	0.201	4.51
Polyimide	0.3	1	1.16
Copper	385	-	-
AFEE PCB (Polyimide + Copper)	8.72	1	1.16
Ti 6Al 4V	7	-	-

Contact conductivities

Materials	Contact conductivity W/(cm^2.K)
Aluminium / Aluminium	0.1650
Aluminium / Composite (T300 1K PW/M76 ; 40% ; 124AW)	0.0109
Aluminium / Titanium (Ti 6Al 4V)	0.0151

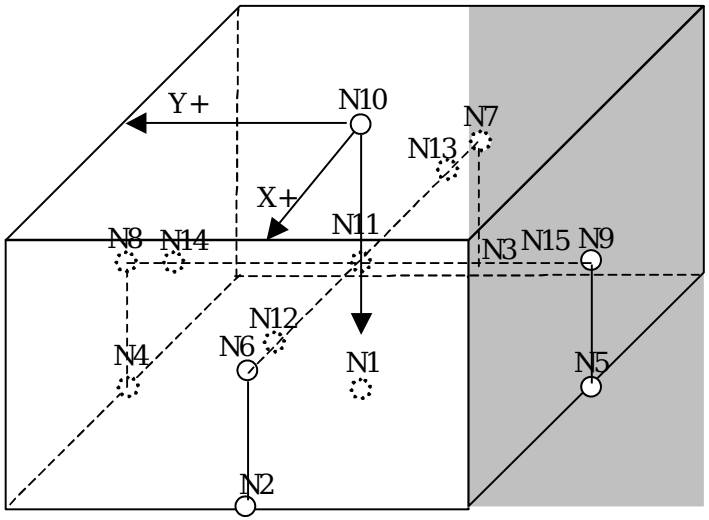
Thermal Model Description

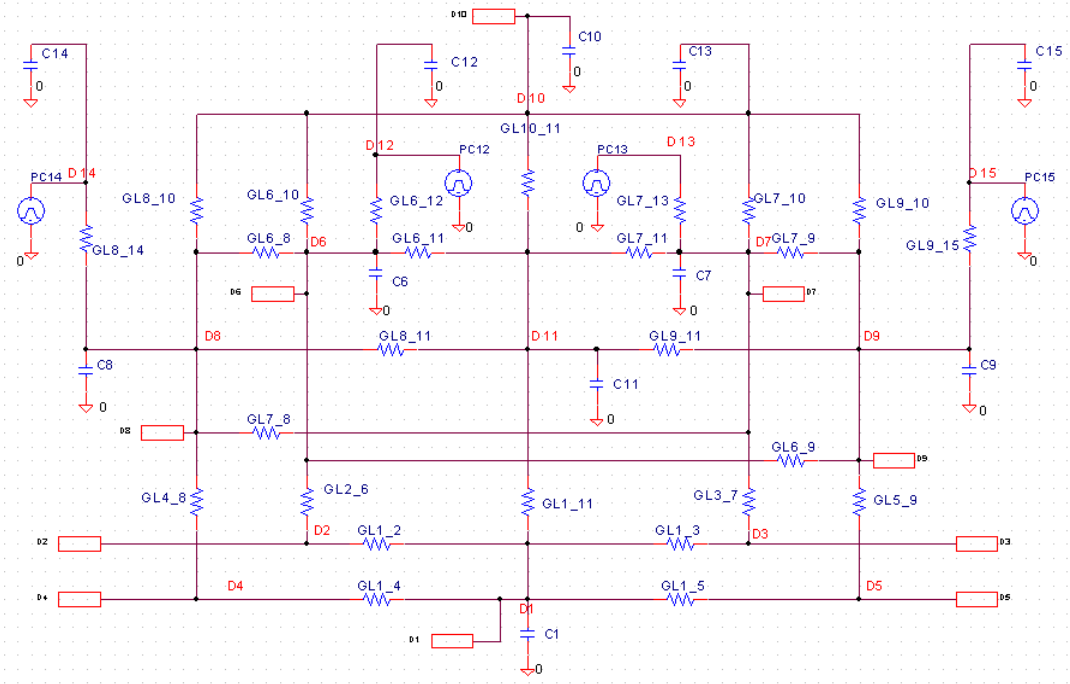
- **No Geometric Model**
- **Math Model (Not SINDA): Electrical Analogical Model Using the Orcad Pspice Simulation Software:**
  - **Voltage (Volt) ⇔ Temperature T (°C)**
  - **Current (Ampere) ⇔ Power P (W)**
  - **Electrical Resistance (Ohm) ⇔ Thermal Resistance (°C/W)**
  - **Electrical Capacitance (µF) ⇔ Thermal Capacitance Cth (J/°C)**
  - **Time (µS) ⇔ Time T (S)**
- **Simplified Thermal Model Simulation**
  - **Consists of 15 Nodes**
  - **Used for the Detailed LAT Thermal Model Simulation**
- **Detailed Thermal Model Simulation**
  - **Consists of 3150 Nodes**
  - **Objectives:**
    - » **Temperature Static Analysis in the Hot and Cold Cases**
    - » **Temperature Transient Analysis: Determination of the Built-up Time (CsI(Tl) Logs, Aluminum Plates, AFEE Boards)**
    - » **Determine the Parameters Which Was Used for the Simplified Thermal Model**

Simplified Thermal Model

- **The Simplified Thermal Model Simulation Is Defined in the Document, LAT-TD-01163-03 (“CAL Simplified Simulation Thermal Model Definition”)**
- **The CAL Consists of 15 Nodes As Follows:**
  - **5 Nodes on the Aluminum Base-Plate**
  - **1 Node on Each AFEE Board**
  - **1 Node on Each Aluminum Side-Panel/Close-Out Plate Assembly (Considered Each as a Single Plate)**
  - **1 Node on the Center of the Composite Structure**
  - **1 Node on the Top of the Composite Structure**
- **Parameters:**
  - **Thermal Conductances Between Nodes (26)**
  - **Thermal Capacitances at Each Nodes (15)**
  - **Power Sources at Each AFEE Nodes (4)**
  - **Thermal Radiation Parameters (Surface , Emissivity) on Each External Sides Nodes (6)**

Simplified Thermal Model

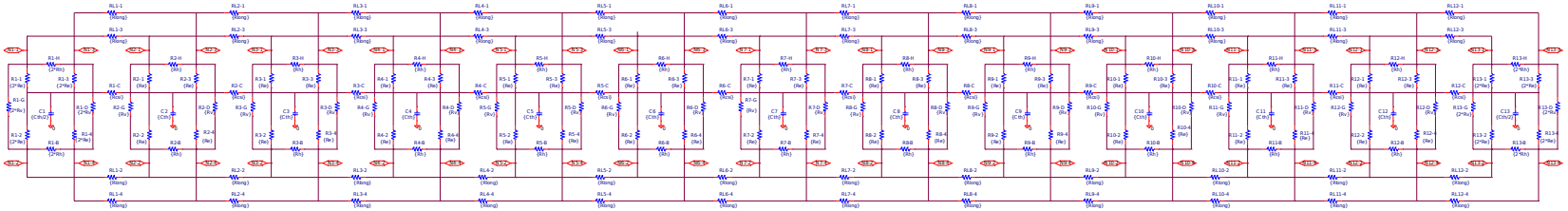




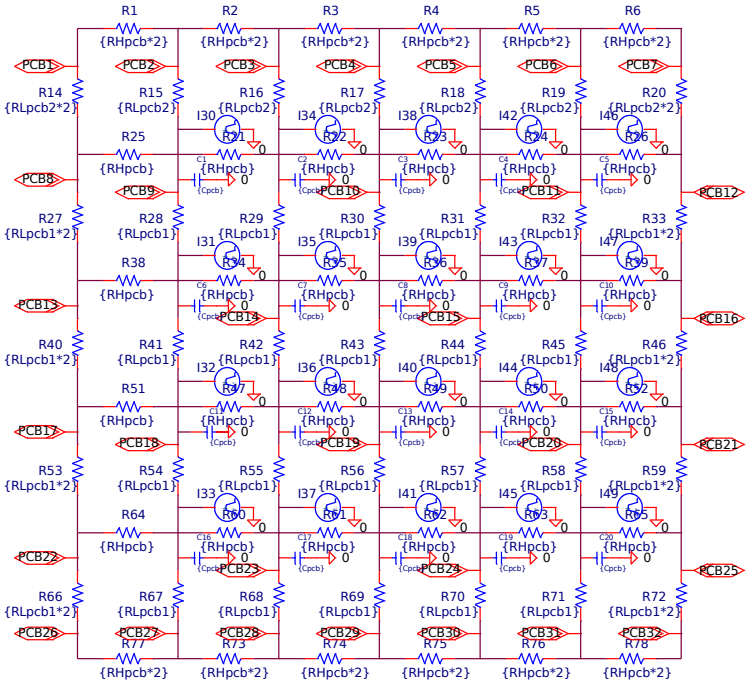
Detailed Thermal Model

- The Complete Simulation Thermal Model is Defined in the Document, GLAST-LLR-TN-054 (“Detailed Simulation Thermal Model Definition of a CAL Module”)
- The CAL Model Consists of the Following Sub-Modules
  - Base Plate: Modeled by a Plate of 5 X 5 Nodes
  - 4 Close-Out Plates/Side Panels: Modeled as a Plate of 7 X 6 Nodes
  - 4 AFEE Boards: Modeled as a Plate of 7 X 6 Nodes
  - Top Frame: Modeled as a Frame of 16 Nodes
  - Composite Structure With CDEs : Modeled by a Network of 2770 nodes
- Radiative and Conductive Interfaces are Modeled with:
  - LAT Grid (Radiative/Conductive)
  - Tracker (Radiative)
  - TEM (Radiative/Conductive)

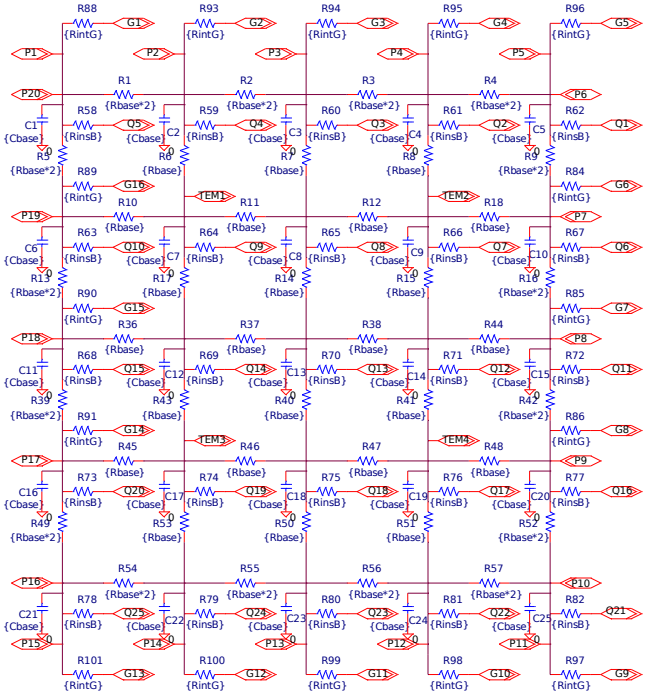
Detailed Thermal Model



Composite CELL/CDE model diagram



AFEE board model diagram



Base-plate model diagram

Thermal Analysis Results

- **Static Results – Good Correlation**
  - **Hot Case**

Location	N° Node	TEMP Ta (°C)	TEMP Tb (°C)	Ta –Tb (°C)
		Simplified model	Detailed model	
Base Plate – Center	1	18.74	18.64	0.1
Base plate –Face X+ Side	2	18.542	18.55	-0.008
Base plate –Face X- Side	3	18.542	18.55	-0.008
Base plate – Face Y+ Side	4	18.542	18.53	0.012
Base plate – Face Y- Side	5	18.542	18.53	0.012
Side panel – Center Face X+	6	19.64	19.4	0.24
Side panel – Center Face X-	7	19.64	19.4	0.24
Side panel – Center Face Y+	8	19.64	19.43	0.21
Side panel – Center Face Y-	9	19.64	19.43	0.21
Composite Structure - Top	10	19.188	19.02	0.168
Composite Structure – Center	11	19.171	19.01	0.161
AFEE board – face X+	12	22.515	22.52	-0.005
AFEE board – face X-	13	22.515	22.52	-0.005
AFEE board – face Y+	14	22.515	22.51	0.005
AFEE board – face Y-	15	22.515	22.51	0.005
Grid	grid	18	18	0
TEM	tem	34	34	0
Tracker	tracker	18.5	18.5	0

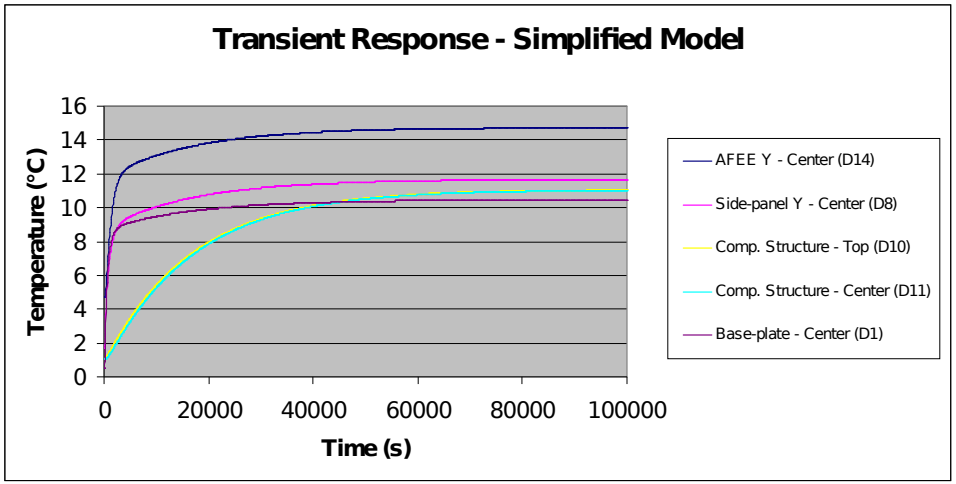
Thermal Analysis Results

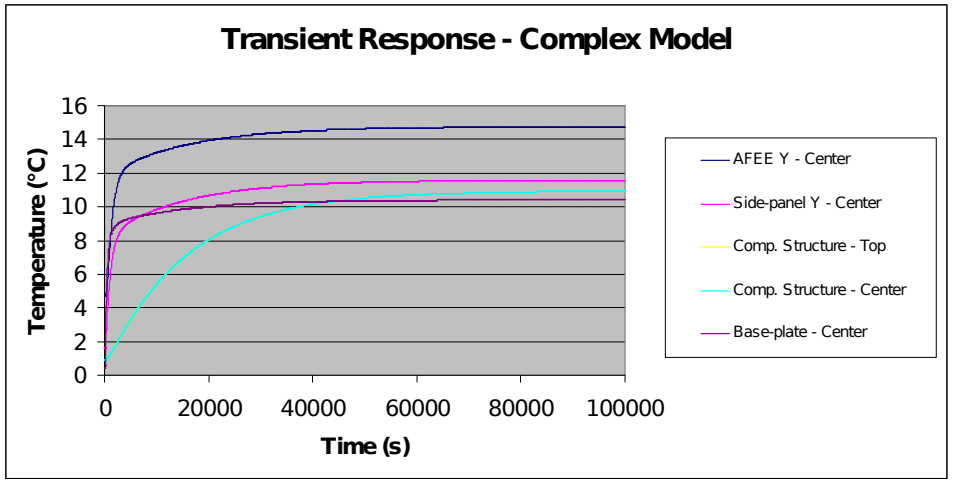
- **Static Results – Good Correlation**
  - **Cold Case**

Location	N° Node	TEMP Ta (°C) Simplified model	TEMP Tb (°C) Detailed model	Ta –Tb (°C)
Base Plate – Center	1	-14.52	-14.57	0.05
Base plate –Face X+ Side	2	-14.588	-14.59	0.002
Base plate –Face X- Side	3	-14.588	-14.59	0.002
Base plate – Face Y+ Side	4	-14.588	-14.61	0.022
Base plate – Face Y- Side	5	-14.588	-14.61	0.022
Side panel – Center Face X+	6	-13.483	-13.72	0.237
Side panel – Center Face X-	7	-13.483	-13.72	0.237
Side panel – Center Face Y+	8	-13.483	-13.69	0.207
Side panel – Center Face Y-	9	-13.483	-13.69	0.207
Composite Structure - Top	10	-14.024	-14.15	0.126
Composite Structure – Center	11	-14.041	-14.15	0.109
AFEE board – face X+	12	-10.608	-10.6	-0.008
AFEE board – face X-	13	-10.608	-10.6	-0.008
AFEE board – face Y+	14	-10.608	-10.4	-0.208
AFEE board – face Y-	15	-10.608	-10.4	-0.208
Grid	grid	-15	-15	0
TEM	tem	-11	-11	0
Tracker	tracker	-17	-17	0

Thermal Analysis Results

- **Transient Results – Good Correlation**
  - **A 10°C Temperature Step was Applied on the Grid in Order to Verify the Correlation Between the Simplified and Detailed Models**





Thermal Design Status

- **Detailed and Simplified Thermal Models Have Been Developed with Material and Thermal Contact Assumptions**

- **The Temperature Build-Up Time of the CDEs is Very Dependent on the Contact Resistances Between Parts (Aluminum-Composite, Titanium-Aluminum, CDE-Composite):**
  - **24:30 hr – 32:00 hr for the Qualification Thermal Cycle**
    - **A Step of Temperature Applied on the Grid: –30°C to +50°C With a Temperature Slope of 10°C / Hour**
    - **Time Determined at +49°C**
    - **Min and Max Contact Thermal Resistances are in a Ratio 1:12**

Thermal Design Status - Continued

- The Detailed and Simplified Models Will Be Updated According to the Thermal Balance Test Results Achieved on the EM
  - Model Update Will Only Affect the Parameter Values
  - The Model of the Structure Will Not Change
- The Current Thermal Simulations Show That the Thermal Design Is Sound:
  - The Max Difference of Temperature Between CDEs is 0.7°C, Accounting for Max Values of Contact Thermal Resistances
- Independent Review of Analysis is Complete